ANNEX
Outer-Cell Forward Link Interference and Building Loss

A CDMA PCS handset will receive interference from the base station transmitters of nearby "outer" cells. Figure A-1 shows this interference, (labeled I_{oc}) vs. the strength of the desired "in-cell" forward link signal P_{in} that would be received by a handset operating outdoors. Hexagonal cell geometry was assumed and the curves were based on $\theta = 0$ (see Figure A-2), although the result is relatively insensitive to θ. It was assumed here that the nominal minimum value of P_{in} (i.e., at the cell vertex) was -104 dBm.
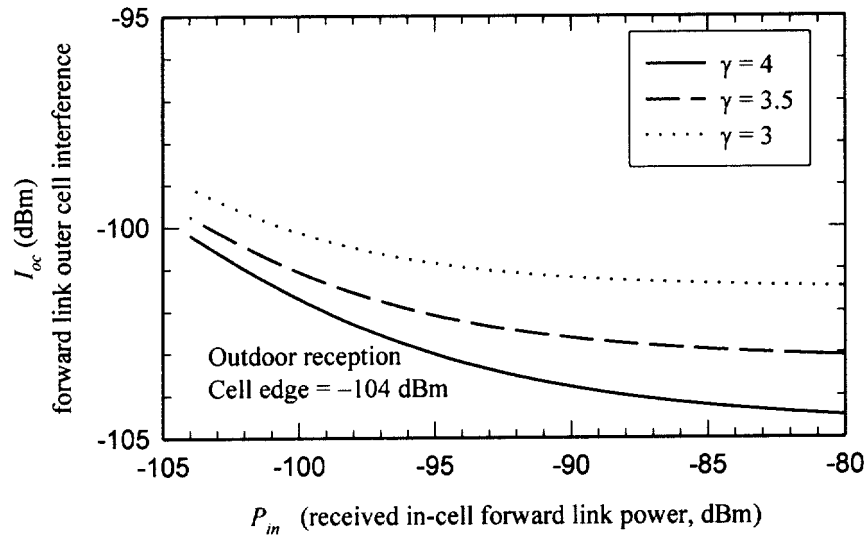

Figure A-1: *Outer-cell interference vs. outdoor forward link power.*
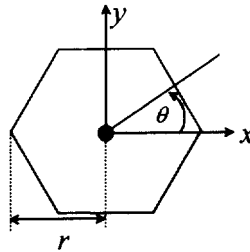

Figure A-2: *Reference geometry for outer-cell interference calculations.*

As can be seen, the outer cell interference (OCI) varies only a few dB over a large variation of P_{in}.

Eq. (3) in the body of this paper can be generalized to include OCI as:

$$\alpha = \frac{1}{M_J}\left(\frac{N}{P_{rx}} + F_{no} + \frac{I_{oc}/L_{bldg}}{P_{rx}}\right) \qquad \text{(A-1)}$$

where L_{bldg} is the additional path loss due to the building, for indoor handsets. Also note that the actual received power is $P_{rx} = P_{in}/L_{bldg}$.

In effect, the OCI acts as additional noise, increasing the noise floor from N to $N + I_{oc}/L_{bldg}$. Unlike N, however, the OCI is not invariant with P_{rx} as is clear from Fig. A-1.

Figure A-3 shows I_{oc}/P_{in}, N/P_{in}, $(I_{oc}+N)/P_{in}$, and $(I_{oc}+N)/N$ vs. the outdoor received power P_{in}. Note that $(I_{oc}+N)/N$ varies little over the range of P_{in}, which suggests that it can be approximated as a constant. The 5-dB line is shown as a reference.
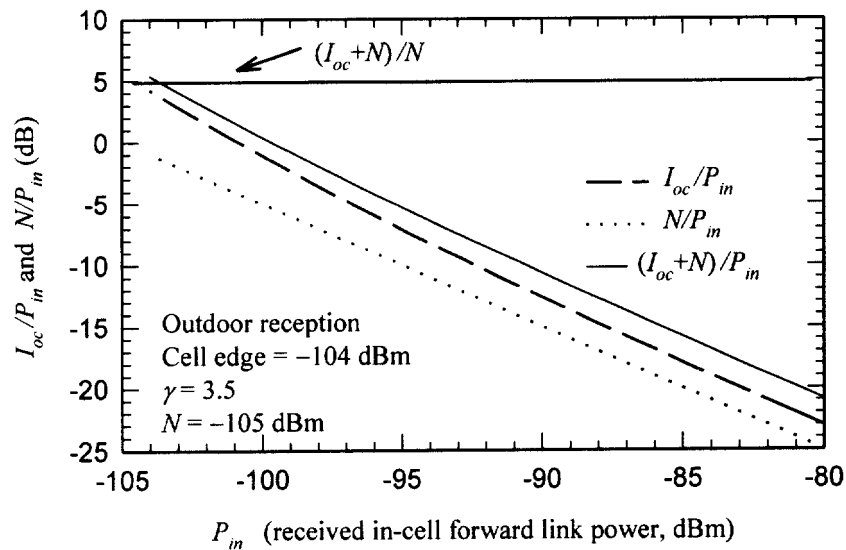

Figure A-3

To determine the constant to be used to represent $(I_{oc}+N)/N$, consider Figure A-4, which shows the power allocation required as a function of the received power.

The points at which the curves cross the α_{max} line are roughly -101.3 dBm, -100 dBm, and -97.5 dBm for $F_{no} = 0$, 0.5, and 1.0, respectively. From Fig. A-3, $(I_{oc}+N)/N$ is on the order of 5 dB in this range, so the effect of the OCI can be approximated using a noise figure of 13 dB instead of 8 dB. Figure A-5 shows curves for $\langle\Delta\alpha\rangle$ and P_b based on this approximation, and Figure A-6 shows the same curves, but based on the actual OCI calculations used to generate Figs. A-1 and A-3. As can be seen, differences between the two sets of curves are very slight.
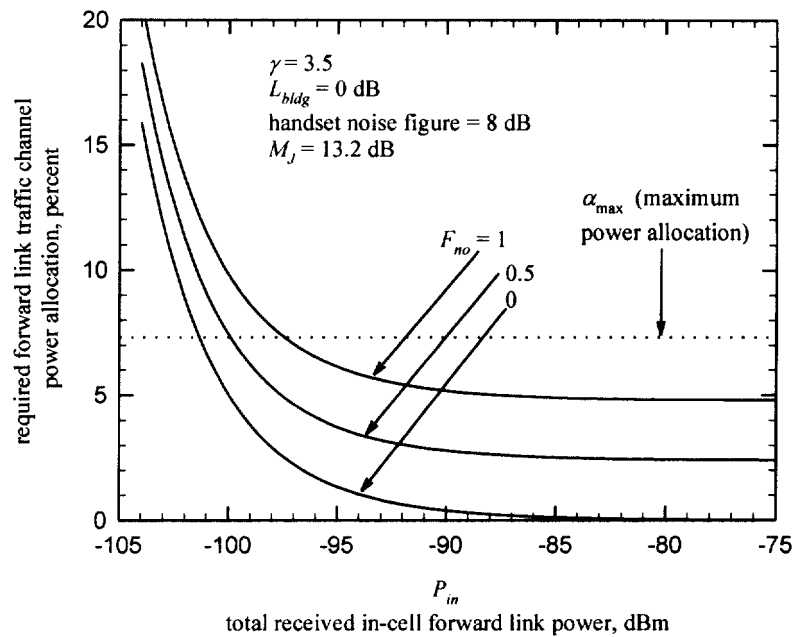
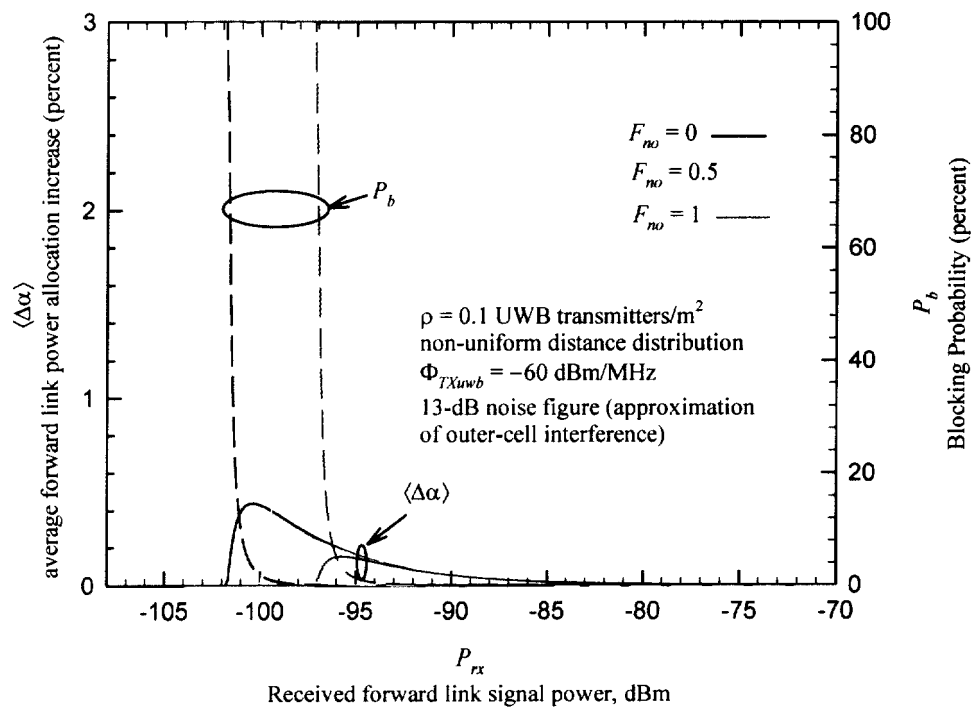**Figure A-4:** *Required power allocation for outdoor operation, with OCI.*

Figure A-5: $\langle\Delta\alpha\rangle$ *and* P_b *calculated by treating OCI as a noise floor increase.*
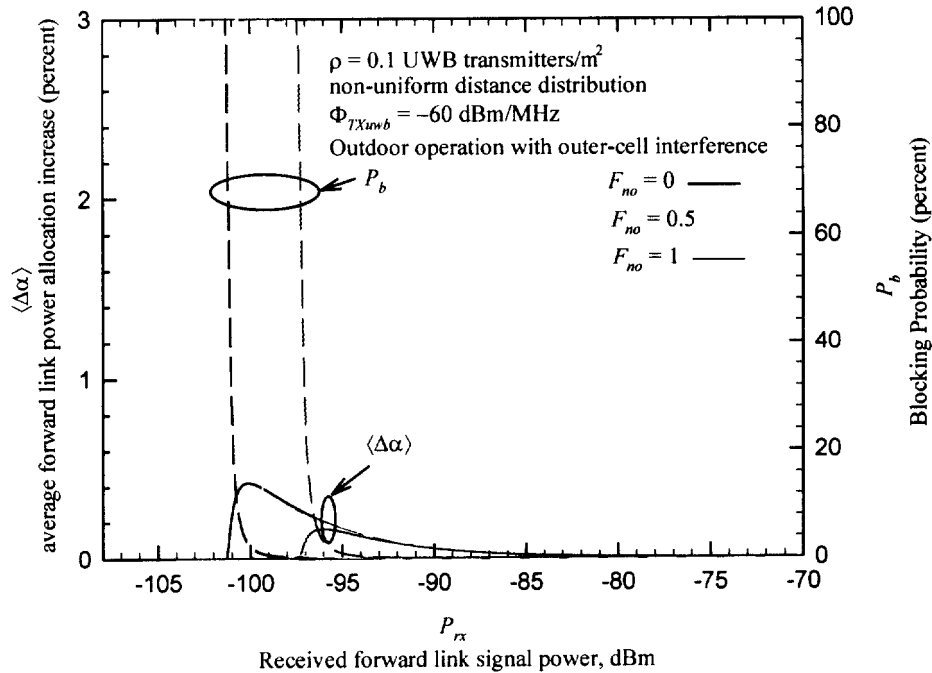
Figure A-6: $\langle \Delta \alpha \rangle$ and P_b calculated using the full OCI computation.

Figure A-7 shows the same curves as Figure A-3, but with a 10-dB building loss. As can be seen, the outer-cell interference makes a difference of less than 1 dB in the overall effective noise floor, and the term $(I_{oc} + N)/N$ appears constant over the range shown.
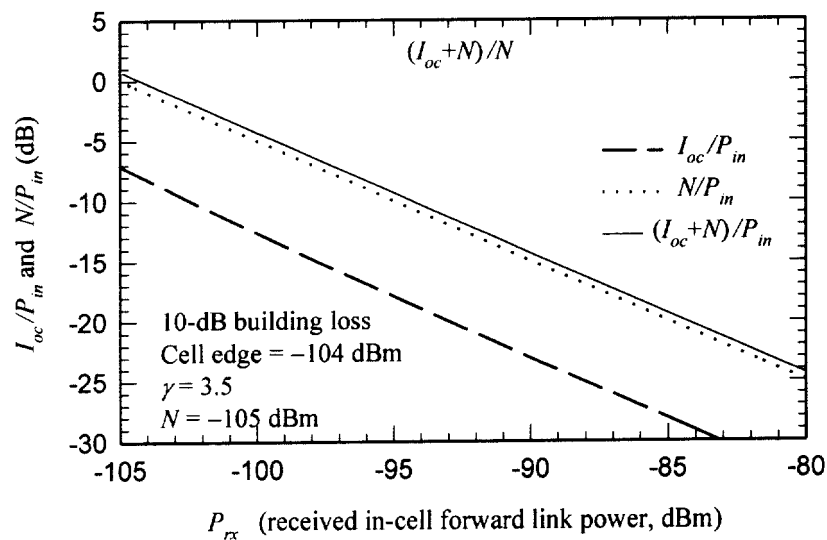

Figure A-7

In sum, the effect of outer-cell interference can be well-approximated for modeling purposes by an increase in the effective handset receiver noise figure. For analysis of in-building performance, outer-cell interference is not a significant factor and can be ignored for even a modest amount of building loss (e.g., 10 dB).

Summary of Testing Performed by Sprint PCS and Time Domain to Characterize the Effect of Ultra Wideband (UWB) Devices on an IS-95 PCS System

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September 12, 2000

As part of a continuing effort to understand the impact of Ultra Wideband (UWB) devices on the performance of an IS-95 (CDMA) PCS system, Sprint PCS and Time Domain have jointly conducted several sets of laboratory and field tests. The purposes of these notes is to summarize those tests and the conclusions drawn from them.

Initially, "cabled" tests using conducted RF paths with splitters, couplers, variable attenuators, and an IS-95 base station simulator (BSS) were used to determine the basic effect of a UWB signal on a PCS receiver. The signal path was coupled directly into the PCS handset antenna port, bypassing the antenna. A diagnostic monitor (DM) connected to the handset data port gave a reading of the handset RSSI (received signal strength indicator), which is the total RF power into the handset receiver. The results suggested that the UWB signal affected the handset in the same way as a noise signal of the same average power spectral density (PSD).

Calculations based on those results, and assuming free-space path loss between the UWB transmitter and the PCS handset did not seem consistent with a limited set of *ad hoc* tests performed with a PCS handset linked to a live PCS system. Generally, it was observed that the UWB transmitter could be nearer to the PCS handset without causing observable speech quality degradation than was predicted by the free-space calculations, but there also was significant variation among the results of the *ad hoc* tests.

One likely reason for this variation is that the effect of a given level of UWB interference on the reception of a PCS handset operating on a live system can be affected by a number of factors, including:
- the total forward link (base-to-handset) power received from the PCS base transmitter
- the fraction of the total forward link power allocated to the traffic channel being used by the handset; the base station varies this dynamically to maintain the required SINR (signal to interference plus noise ratio).
- the amount of interference received from other channels (codes) on the base station, and from other base stations (outer cell interference).
- Ambient noise and interference in the PCS band from other (non-PCS) sources.

Accordingly, it was decided that over-the-air tests under controlled conditions were needed. Two types of tests were planned. The first type would focus on the propagation loss and the minimum separation distance, when the desired signal and other interference are known and completely controllable. This suggested the use of a base station simulator communicating over the air with the handset in a controlled RF environment, such as an anechoic (RF-absorber-lined) chamber. The second type of test would focus on performance in an operational system in which other-cell interference, in-cell interference, and forward link power allocations could be controlled and monitored. These two types of tests were performed and are summarized below.

Over-the Air Tests with a Base Station Simulator

These tests were performed on May 18/19, 2000 by engineers from Sprint PCS and Time Domain in an anechoic room. Figure 1 illustrates the test setup.
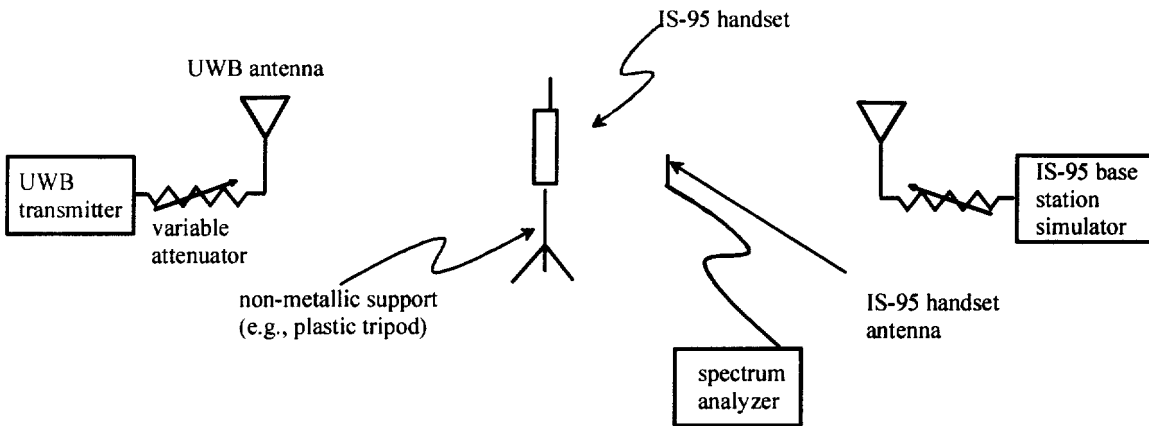

Figure 1: *Over-the-air test setup concept.*

The objectives of these tests were to determine:

- The field strength sensitivity of the PCS handset, both alone (mounted on a tripod) and held by a user (i.e., as opposed to the power sensitivity when the signal is directly applied to the antenna port).
- The effect of the relative orientation of the UWB and PCS handset transmit antennas (polarization and antenna directivity variations).
- The effect of the human body on the coupling between the UWB device and the PCS handset ("head loss", etc.).
- The received signal power vs. distance from the UWB transmitter.
- The difference between the power measured with a spectrum analyzer using a PCS handset antenna, and that measured using a calibrated measurement antenna.
- The received signal-to-UWB interference ratio threshold level for the handset (the level that the signal-to-interference ratio must exceed for adequate reception)

A detailed description of the tests, analysis of the results, and the conclusions are provided in the Annex to these notes. In brief, the findings were:

1. As expected, adherence to the free-space path loss vs. distance relationship was observed; i.e., the path loss at 2 GHz, in dB, is $L = 38 + 20 \log d$ where d is the separation between transmitter and receiver, in meters. This is a good model for the path loss between the UWB device and the PCS handset, which normally must be fairly close together for an interference effect to occur.

2. For the particular handset used in the tests, the antenna seems to be optimized for the transmit band rather than the receive band. During the test, the antenna "gain" was measured as –4.6 dBi at the received frequency used (1967.5 MHz). A subsequent measurement of the handset antenna reflection coefficient vs. frequency (using a network analyzer) was used to compute antenna gain vs. frequency (shown in the Annex), and gives results consistent with the gain measured during the anechoic room tests. For a

given RSSI from the base station, the effect of this additional loss is to allow the UWB device to be nearer to the handset, compared to a handset with an ideal lossless receive chain, to cause a given level of interference to the handset.

3. The RSSI seen by the handset, as measured using the diagnostic monitor (DM) seems to be about 3 dB below that calculated using the known transmit power, cable losses, antenna gains, and path loss. This may have to do with the way in which the handset measures RSSI, or may be the result of matching or other losses (e.g., duplexer) between the antenna and the receiver. Based on the E_b/N_0 calculation (see the Annex for details), it is likely the latter.

4. E_b/N_0 was calculated here as a function of the base station simulator output power. The results show that at the power output for which frame errors begin to occur, E_b/N_0 is near 5 dB, which is about right for a forward link operating at rate set 2 in a non-faded environment.

5. The power received by the handset over a free-space path, when held by a user, varies slightly with the handset antenna polarization (roughly 1.5 to 2.5 dB of total variation). The received power varies significantly (12 to 15 dB, depending on the handset polarization) with the orientation of the user relative to the path between the transmitter and the handset. This suggests that blockage of a line-of-sight path due to the user's head is substantial.

6. The effect of the UWB interference on the handset (with respect to link performance measures such as frame error rate) appears to be the same as that of a Gaussian noise source with the same power spectral density within the PCS band.

Tests on a Live System Testbed

The IS-95 forward link has a fixed maximum transmit power. Of this, about 20% is allocated to the overhead channels (pilot, sync, and paging). The remaining 80% is divided among the traffic channels. The forward link attempts to allocate to each traffic channel only the amount of power necessary to maintain the integrity of the channel. If the path loss or interference increases, the power allocation is raised to compensate. There is an upper limit on the fraction of the total power that can be allocated to a given traffic channel. If the power required to maintain link integrity exceeds this limit, the link will drop.

From the results of the anechoic room tests, the interference power received by a PCS handset a given distance from a UWB transmitter can be calculated. Given the forward link power received by the handset (desired signal) and the forward link interference (in-cell and outer-cell), the incremental forward link power allocation required to compensate for the interference from a UWB transmitter at a given distance can also be calculated. Finally, given the maximum allowed forward link power allocation, the distance between the UWB transmitter and the PCS handset at which the required power allocation exceeds the maximum (and the call drops) can be calculated (for a given received forward link power).

The purpose of the second set of tests was to verify those calculations. This required that the total forward link power received by the handset (the RSSI measured with the DM) and the forward traffic channel power allocation be monitored. It also required that additional interference (e.g., from other base stations) be removed or at least known. To realize these

conditions, the Sprint PCS test facility was used. Only a single cell was activated, so there was no outer-cell interference. As noted, the RSSI was measured and recorded with a timestamp at the handset using the DM, and the traffic channel power (TCP) was monitored and recorded with a timestamp at the base station.

A total of six cases were investigated: high, moderate, and low RSSI levels, each first with only a single traffic channel active, then with the cell 50% loaded with other traffic channels. Unfortunately, the base station failed to record the TCP data for three of these cases, and in the others there were significant gaps in the TCP data, so the information available for analysis is fairly limited. However, for the case of moderate signal level with no additional load, there is enough information to analyze the behavior of the system.

In that case, the RSSI (total forward link power received by the handset) ranged from –92 dBm to –96 dBm. Because there was only a single active traffic channel for this case, that received power was divided among the overhead channels and the single traffic channel. Based on the ratio of the transmitted TCP to the total transmitted power, the power received on the traffic channel can be calculated as follows. Without UWB interference, the TCP fluctuated between about 16 dBm and 21 dBm. Assuming the transmitted power for the overhead channels was 35 dBm (20% of the 16-watt maximum forward link transmit power), then the average traffic channel transmit power was about 14-19 dB below the overhead channel power. Since there was only one traffic channel active, the total transmitted forward link power was also about 35 dBm. Therefore, the received traffic channel power was in the range of –106 to –115 dBm most of the time. With a noise figure of 8 dB, the handset receiver noise floor would be –105 dBm. For a processing gain of 19 dB (rate set 2) and an E_b/N_0 requirement of about 6 dB, the received signal could be as low as about 13 dB below the noise floor, or about –118 dBm. The recorded traffic channel power range therefore seems consistent with the needs of a handset which is experiencing the observed RSSI fluctuations and possibly some additive external ambient noise.

The maximum observed traffic channel power seemed to be 29 dBm, or 6 dB below the power used by the overhead channels. In that case, the received traffic channel power would be 20% of the total RSSI, or –99 to –103 dBm. This would allow the handset to tolerate interference in the range –86 to –90 dBm. From the anechoic room tests, the power received from a UWB transmitter a distance d from the handset is roughly $I_{uwb} \cong -95 - 20\log d$ dBm. Thus, the minimum UWB distance would be in the range of 0.35 meters (roughly 1 foot) to 0.56 meters under these conditions. It was in fact observed in the test that when the UWB transmitter was moved to within 1 foot of the handset, the traffic channel power rose to 29 dBm (although there was some fluctuation), and the call dropped. It should be noted that with a loaded system, this same minimum distance range would be observed at a RSSI about 7 dB higher than in this test (i.e., –85 to –89 dBm), because the total transmitted power would be 42 dBm rather than 35 dBm.

Although the available data set from this live testbed experiment is limited, it does seem consistent with interference calculations based on the tests in the anechoic room and with the way in which the forward link is understood to manage its traffic channel power allocation.

Summary

Overall, the tests described here have provided enough information to allow the effect of multiple UWB transmitters, with some specified transmitted power and spatial density (average number of devices per square meter) to be modeled and simulated. Such studies can be used to determine the limits on power spectral density (in the PCS band) necessary to allow UWB devices to coexist with IS-95 systems with an acceptable performance impact.

ANNEX
Notes on Sprint PCS/Time Domain
Anechoic Room Testing

SUMMARY

This Annex discusses conclusions that can be drawn from tests that were done in an anechoic room in Huntsville on May 18/19, 2000. These tests were part of an ongoing effort to characterize the effect of an ultra wide band (UWB) transmitter on the forward link of an IS-95 CDMA PCS system operating near 1.9 GHz.

As expected, the effect of the UWB device on handset receiver performance (e.g., bit error rate or frame error rate) appears the same as that of random noise with the same average power in the PCS handset receive band, and free space propagation applies. The two main surprises were (1) there is a significant amount of loss in the handset receive path; and (2) the power received by the handset in a line-of-sight situation is strongly affected by the user's orientation with respect to the transmitter (loss due to the user's head appears considerable).

While the handset receive path loss will make the handset less sensitive to UWB interference, for a given RSSI from the base station, it is important to note that the large receive path attenuation pertains to the specific handset used in the experiment (Samsung 3500). It is unclear whether this can be generalized for application to interference analysis. It might be worthwhile to obtain specifications for other handsets that can be used with a PCS network.

Handset Antenna, RSSI, and Sensitivity
Summary
The first group of tests were performed without the UWB transmitter. The BTS simulator was connected to a calibrated horn antenna through a cable with known loss. The received signal power was first measured with a spectrum analyzer connected to another calibrated horn/cable combination 1 meter away from the transmit antenna. The measured signal power differed from that predicted using free-space path loss by only 0.12 dB. The PCS handset antenna was then connected to the spectrum analyzer in place of the horn. The measured power indicated that the effective gain of the PCS handset antenna at the test frequency (1967.5 MHz) was –4.6 dBi. This is consistent with the manufacturer's data, which specifies a gain of 0 to –4.55 dBi, and also with subsequent measurements made with a network analyzer of the antenna reflection coefficient. Details are provided later in these notes.

A functioning PCS handset was then substituted for the spectrum analyzer/antenna combination. The received signal strength indicator (RSSI) from the handset was observed using the diagnostic monitor (DM) as the BTS power output was varied. The handset RSSI readings seem to be about 3 dB below the signal delivered by the antenna, based on calculations. It is not clear whether this is due to some sort of matching or other loss (e.g., duplexer), or a calibration problem with the handset's RSSI function. It might be explained in part by a difference between average power (of the modulated signal) and peak envelope power. The BTS power output was reduced until frame errors were observed.

Next, the handset was held by a user at three different polarizations (vertical, 45°, and horizontal) for each of three different user orientations (handset antenna toward BTS antenna, to the side, and away from the BTS antenna), and receiver power measurements were made.

Analysis

Given the cable loss and antenna gain at the BTS, the power received by an ideal lossless isotropic antenna 1 meter from the transmit DRG horn can be expressed as:

$$P_{RXi} = P_{TX} + G_{TX} - L_{CTX} - L_{FS} = P_{TX} - 33.65 \, \text{dBm}$$

where $G_{TX} = 7.6 \, \text{dB}$ (transmit antenna gain) $L_{CTX} = 3.25 \, \text{dB}$ (cable loss on the transmit side) and $L_{FS} = 38 \, \text{dB}$ (free-space path loss at 2 GHz for 1 meter separation).

If the 4.55-dB loss in the PCS handset antenna is taken into account, then the RF power delivered by the handset antenna is

$$P_{RXa} = P_{TX} - 38.2 \, \text{dBm}$$

Fig. 1 shows P_{RXi} and P_{RXa} along with the RSSI readings taken from DM.

The RSSI readings compress near the low end, but this is likely at least partially due to the handset receiver's noise floor. With a 6-dB noise figure, the noise floor is −107 dBm (as an example). Assuming the RSSI reading reflects the total signal plus noise power, then the RSSI would be

$$RSSI = 10 \log\left(10^{P_{RX}/10} + N\right)$$

The red dashed and blue dotted curves in Fig. 1 used this equation with $P_{RX} = P_{TX} - 41.2$, which simply reflects the empirical observation that at high RSSI, the reading is roughly 3 dB below the calculation using the −4.55 dBi antenna factor. The red dashed and blue dotted curves were based on noise figures of 6 dB and 8 dB, respectively.

At the low end of this curve (for $P_{TX} < -60 \, \text{dBm}$), the receiver noise becomes a significant part of the total RF power. The details of the handset's RSSI measurement technique are unknown (i.e., whether it attempts to perform any multi-sample averaging), but it appears that when the total power is dominated by noise, the RSSI measurements vary significantly. This may simply reflect the normal variation of the noisy signal.
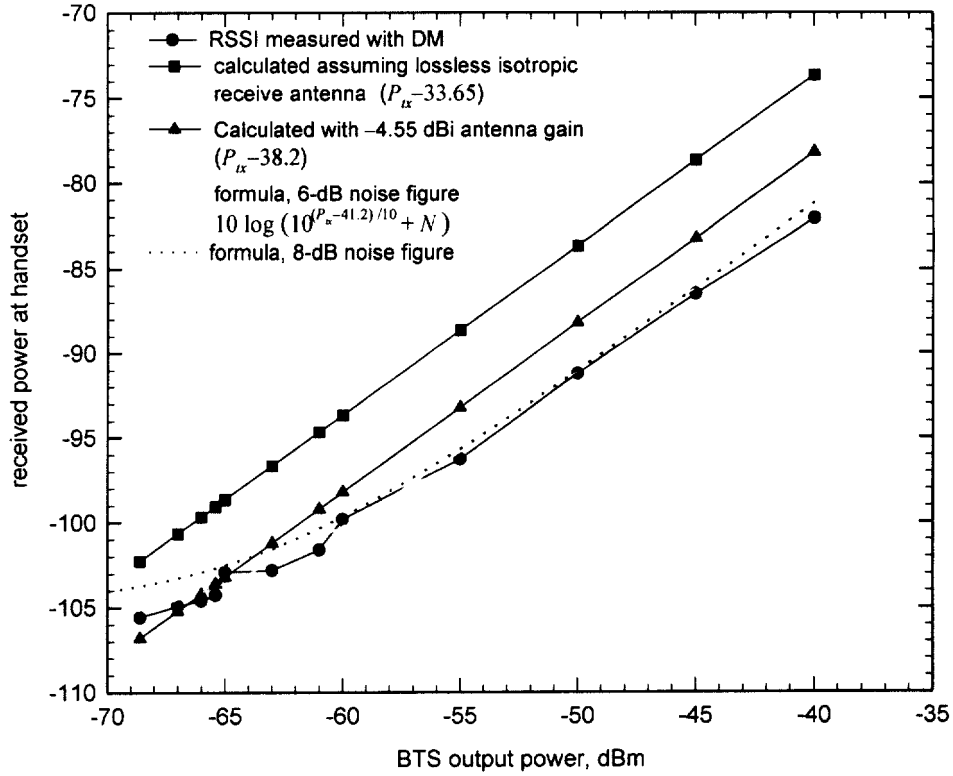
Figure 1

Calculation of E_b/N_0

The traffic channel power allocation was -10.3 dB (that is, 10.3 dB below the total forward link power). With rate set 2 the rate is $R = 14.4\,\text{kb/s}$, so the processing gain is 19.3 dB and E_b/N_0 is

$$E_b/N_0 = P_{RX} - N - 10.3 + 19.3\,\text{dB} = P_{RX} - N + 9$$

With $P_{RX} = P_{TX} - 41.2$, this becomes

$$E_b/N_0 = P_{TX} - 32.2 - N \ \ \text{dB},$$

which is shown in Fig. 2 for $N = -107\,\text{dBm}$ (solid black) and $N = -105\,\text{dBm}$ (dashed red).

The test data indicate that a BTS transmit power as low as -67 dBm can be used without errors. This corresponds to $E_b/N_0 = 7.8\,\text{dB}$ for $N = -107\,\text{dBm}$ and 5.8 dB for $N = -105\,\text{dBm}$. When the BTS transmit power was reduced to -68.6 dBm, errors began to occur. At a BTS transmit power of -69.2 dBm, the call was dropped.
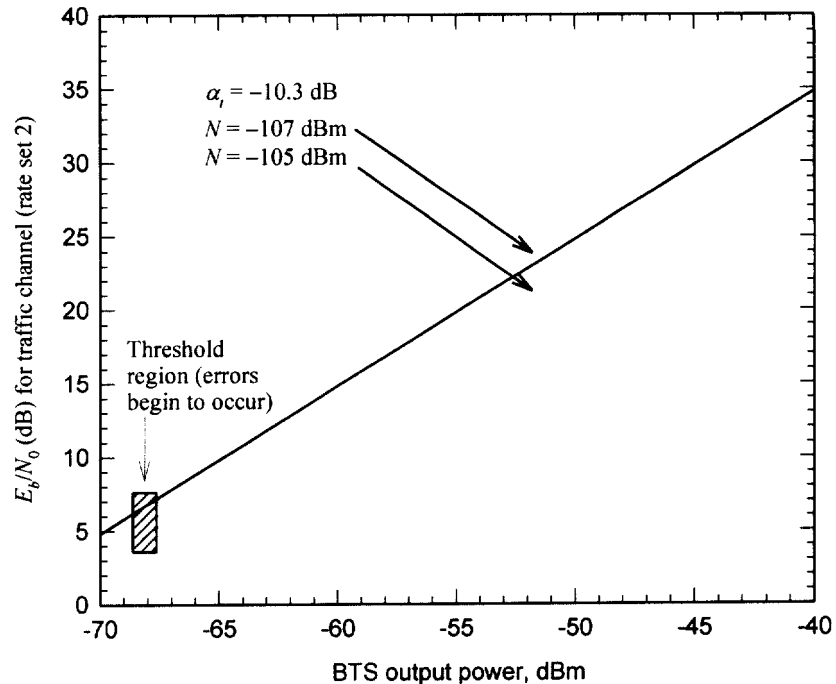
Figure 2

The E_b/N_0 threshold appears to be on the order of 5 dB, which is consistent with forward link reception at rate set 2 in a non-faded environment.

Polarization/Orientation Effects

The effect of handset polarization and user orientation are summarized in the table below. Each entry represents the difference in received power (dB) relative to the base case (vertical polarization, no user present).

	V	45°	H
HS toward BTS	+3.7	+2.2	+4.2
HS to side	−8.4	−7.3	−5.8
HS away from BTS	−8.8	−10.0	−11.0

These results suggest that "head loss" is a significant factor with respect to interference received from a nearby UWB transmitter. The increase in received power observed when the handset was oriented toward the BTS antenna may be due to a slight variation in distance, or an improvement in tuning due to the presence of the hand and head, or some combination.

Effect of UWB Interference

The UWB transmitter was connected to its antenna through a cable and variable attenuator and positioned 1 meter from the PCS handset. The total UWB output power, after the 12-dB cabling and attenuator loss, was −16.43 dBm, as read by the HP437B power meter. Adjusting for the bandwidth ratio, this translates to an average effective noise power into the PCS band of −49.1 dBm. According to the test notes, the spectrum analyzer reading was −49.2 dBm.

The UWB pulse rate was 5 MHz, so the absolute peak power into the analyzer, when making this measurement, would be +14.4 dBm. Subtracting 20 dB for the attenuator gives –5.6 dBm into the front end of the analyzer, which is well below the third order intercept of the analyzer front end (+17 dBm).

The effective UWB antenna gain was given as 0.8 dBi. With a 1-meter separation, the interference power that would be received from a lossless isotropic antenna would be

$$P_{Ri\,\text{UWB}} = -49.2 + 0.8 - 38 = -86.4\,\text{dBm}.$$

The power received by the same antenna from the BTS would be

$$P_{Ri\,\text{BTS}} = P_{TX\,\text{BTS}} - 33.65\,\text{dBm}.$$

Given a traffic channel power allocation of α_t, the traffic channel power that would be received from the lossless isotropic antenna would be

$$P_{i\,\text{TRAF}} = P_{Ri\,\text{BTS}} + \alpha_t$$

With a processing gain of G_p (dB), E_b/N_0 is

$$E_b/N_0 = G_p + P_{i\,\text{TRAF}} - P_{Ri\,\text{UWB}}$$

For $G_p = 19.3\,\text{dB}$, this becomes

$$E_b/N_0 = 19.3 + P_{TX\,\text{BTS}} - 33.65 + \alpha_t + 86.4 = 72 + P_{TX\,\text{BTS}} + \alpha_t$$

For each of three polarizations of the UWB antenna (vertical, 45°, horizontal) the BTS power output was reduced enough to produce a 2% frame error rate (FER), then further reduced until the FER was 100% and the call was dropped. The PCS handset antenna was vertically polarized.

The values of $P_{TX\,\text{BTS}}$ corresponding to a 2% FER are shown in the table below for each of the three UWB polarizations, for $\alpha_t = -10.3\,\text{dB}$. The E_b/N_0 threshold for an unfaded environment should be about 5 dB, with the forward link operating at rate set 2.

	V	45°	H
$P_{TX\,\text{BTS}}$ (dBm)	–58.6	–56.4	–55.1
E_b/N_0 (dB)	3.1	5.3	6.6

Note that the handset antenna and matching losses were not included in the calculation, because their effect on the desired signal and the interference is the same. The results are roughly consistent with expectations. The worst case seems to be a horizontally polarized

UWB antenna. For that case the result differs from prediction by about 1.5 dB, which is a reasonable margin of error given the nature of the test. It appears that the UWB transmitter affects the handset in the same way as a Gaussian noise source of the same power spectral density.

Next, the handset was held by a user and the polarizations of the handset and UWB antenna, as well as the user orientation, were varied. The BTS power output at which frame errors began to occur was noted. The results were roughly consistent with those of the other measurements of the effects of polarization and orientation variations. The worst case observed was when the BTS and UWB antennas were vertical and the handset antenna horizontal, with the user oriented such that the handset was away from the BTS antenna. In that case, frame errors were observed with $P_{TX\,BTS} = -46.9\,\text{dBm}$.

Received Power vs. Distance

Measurements of power received from the UWB transmitter were made using both a spectrum analyzer and a power meter, located at different distances from the UWB transmitter. The variation of received power with distance was consistent with free space path loss (6 dB/octave). Relevant parameters are:

UWB power output (measured with power meter)	-1.77 dBm
Attenuator	-6 dB
Cable losses	-6 dB
Transmit antenna gain	$+0.8$ dB
Path loss	$-38 - 20 \log d$
Receive antenna gain	$+7.59$ dB
total received power (predicted)	$-43.38 - 20 \log d$ dBm

The table below shows the calculated value and the actual value measured with the power meter.

	total power (dBm)	
d	P_{calc}	P_{meas}
2.0 m	-49.4	-47.4
1.0	-43.4	-41.6
0.5	-37.4	-35.8
0.25	-31.4	-30.3

These tests were repeated with the horn antenna replaced with the PCS handset antenna, assumed to have a receive gain of -4.6 dBm. The calculated and measured total UWB power (power meter measurement) agreed to within less than 1 dB in this case, except for $d = 0.25$ meters.

Handset Antenna Performance

To corroborate the observed antenna gain, the antenna voltage reflection coefficient (denoted here as ρ_v, which is a complex quantity) was measured as a function of frequency using a network analyzer. The antenna gain can be related to ρ_v by

$$G = G_{max} + 10\log\left(1 - |\rho_v|^2\right) \quad \text{dBi}$$

where G_{max} is the gain with $\rho_v = 0$. Fig. 3 shows G vs. frequency for two cases: an ideal lossless dipole (2 dBi gain), and an antenna with 0 dBi maximum gain (to account for an imperfect pattern and ohmic losses). The manufacturer's data specify the gain of the antenna as ranging from 0 dBi to –4.55 dBi.
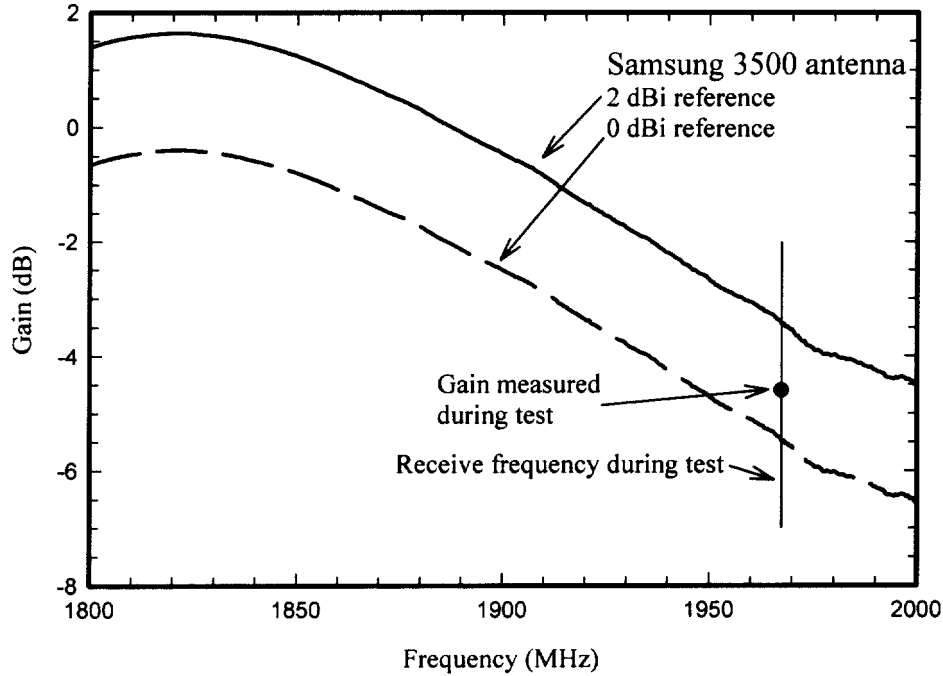

Figure 3: *Calculated handset antenna gain based on reflection coefficient measurements.*

As can be seen, the gain measured during the test (–4.6 dBi) falls roughly midway between the 0- and 2-dBi reference curves shown. It appears that the antenna is optimized for the handset transmit band (1850-1910 MHz) at the expense of a performance degradation in the receive band (1930-1990 MHz).

UWB Minimum Distance vs. RSSI

These test results can be used to predict the UWB separation distance corresponding to a particular E_b/N_0, given the total power received from the base station and the traffic channel power allocation. The expression for E_b/N_0 is

$$E_b/N_0 = G_p + RSSI + \alpha_t - I_{uwb}$$

where G_p is the processing gain (19.3 dB for rate set 2), *RSSI* is the RSSI measured by the handset (dBm) **with the UWB off**, α_t is the traffic channel power allocation in dB, and I_{uwb} is the UWB interference in dBm, which is calculated as follows.

If P_{TXuwb} is the total average transmit power (i.e., as measured with a power meter), then the effective transmit power in a PCS channel is $P_{TXuwb} - 32.7$. The path loss is $38 + 20\log d$, where d is in meters, and the additional loss due to the handset antenna/matching is 7.6 dB. Therefore

$$I_{uwb} = P_{TXuwb} - 32.7 - 38 - 20\log d - 7.6 = P_{TXuwb} - 78.3 - 20\log d$$

This gives

$$E_b/N_0 = RSSI + \alpha_t - P_{TXuwb} + 97.6 + 20\log d \quad \text{(dB)}$$

For example, with $P_{TXuwb} = -17\,\text{dBm}$, $E_b/N_0 = RSSI + \alpha_t + 114.6 + 20\log d$

Fig. 4 shows the required $RSSI + \alpha_t$ vs. d for E_b/N_0 of 5 dB and 7 dB.
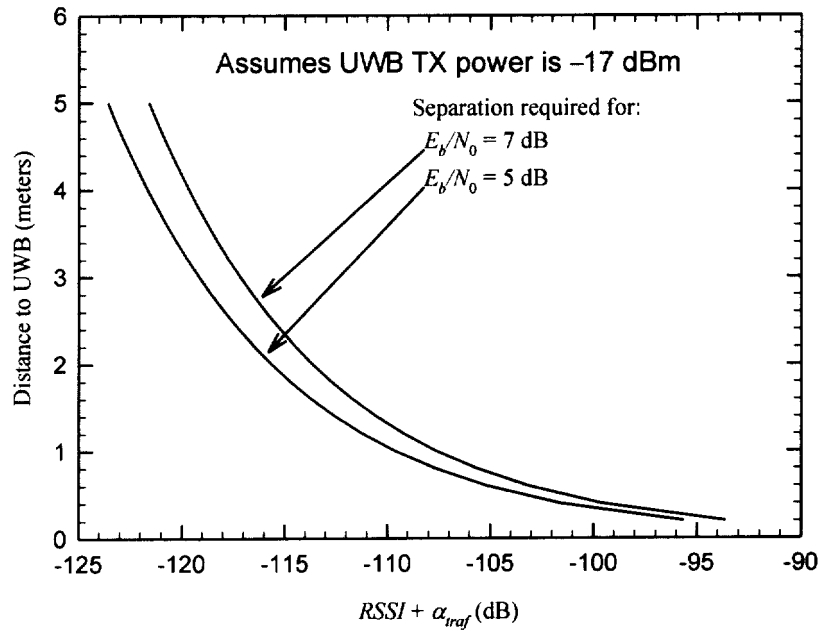

Figure 4